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鲍鱼幼体优质饵料的筛选、培育及其应用研究

Screening, Culture and Application of high Quality Food for Abalone Larval

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摘 要

本论文研究了 2005 年 9 月至 2007 年 12 月期间，福建省东山县和漳浦县沿海鲍鱼育苗场的九孔鲍（*Haliotis diversicolor supertexta*）以及皱纹盘鲍（*Haliotis discus hannai*）育苗池附着基上底栖硅藻群落组成及其育苗早期底栖硅藻群落的变化规律，探讨了近年来鲍鱼早期育苗过程中发生的“脱板病”与底栖硅藻群落之间的关系。对鲍鱼早期幼体附着基上常见的五种底栖硅藻进行分离和培养。并分别利用五种底栖硅藻进行了现场的育苗试验，比较了五种底栖硅藻各自的优劣点。最后找出一个简单、有效的方式提高鲍鱼幼体的成活率。结果如下：

（1）鲍鱼育苗池聚乙烯薄膜附着基上共鉴定出硅藻 30 属 61 种。主要来自 5 个属，分别为菱形藻属（*Nitzschia*）8 种，舟形藻属（*Navicula*）8 种，曲壳藻属（*Achnanthes*）4 种，双眉藻属（*Amphora*）5 种，卵形藻属（*Cocconeis*）3 种，卵形藻属的种类数虽然比其它 5 个属少，但细胞数所占的百分比却明显高于其它属；

（2）鲍鱼育苗池聚乙烯薄膜附着基上底栖硅藻以小型和微型的种类为主。生长类型以附着为主，附着形式则以壳面附着(俯卧)和壳缝附着形式为主，运动能力较弱的硅藻占多数。比较分析不同育苗效果的鲍鱼幼体附着基上底栖硅藻群落的组成发现，脱板严重的底栖硅藻群落的种类组成中，运动能力较强的藻类细胞密度百分比普遍高于同期同批次育苗未发生脱板的藻类细胞密度百分比，变化范围一般在 14.28%～23.04%。

（3）2006 年 8 月至 2006 年 12 月，完整的一次（四个育苗池）鲍鱼育苗试验结果表明：①鲍幼体附着基上底栖硅藻群落的连续变化较为明显。底栖硅藻群落的多样性表现在育苗中期高于育苗前、后两期。优势种虽然在不同的培养时间有一些差异，但盾卵形藻微小变种是鲍幼体附着基上底栖硅藻群落中，大部分育苗时间内的优势种，特别在育苗后期，其藻类细胞密度百分比普遍达到 90%以上，而咖啡双眉藻、柠檬曲壳藻、多枝舟形藻及新月筒柱藻则主要出现在育苗的前中期。② 虽然在不同的采样期间，鲍鱼幼体的生长速率不相同，但实验结束时。不同育苗池内的鲍鱼幼体壳长平均都达到 3.38cm 左右，统计分析差异性不显著（P>0.05）。③实验结束时，不同鲍鱼育苗池鲍鱼幼体的成活率差异很大;且以底栖硅藻较稳定的群落培养的鲍鱼幼体成活率较高，统计分析表明差异性非常显著（p<0.05）。

（4）从同期育苗成功和育苗失败的样品分析比较初步得出，育苗成败与附着基上底栖硅藻群落的稳定性有很大的关系，发生脱板的样品中底栖硅藻群落的多样性变异系

数都较未发生脱板的大，前期，育苗成功的样品中，底栖硅藻群落中优势种细胞密度百分比较育苗失败的样品高;后期,两份样品都具有相同的优势种类即盾卵形藻微小变种。

（5）不同育苗期间，鲍早期幼体附着基上底栖硅藻群落特征的比较，初步得出：①同批次育苗后期多样性指数普遍低于育苗前期,且皱纹盘鲍幼体附着基上硅藻群落多样性指数较九孔鲍幼体附着基上底栖硅藻群落高。②丰富度则是育苗中期普遍高于育苗前、后期，且皱纹盘鲍仍是高于同期九孔鲍的。③优势度与均匀度的变化趋势则与丰富度的变化趋势相反，育苗前、后期较高，且同期九孔鲍幼体附着基上硅藻优势度高于皱纹盘鲍，均匀度则是皱纹盘鲍高于九孔鲍。

（6）鲍幼体肠道分析表明，不同壳长鲍幼体的摄食特性与底栖硅藻形成的生物膜的立体结构组成息息相关。即鲍幼体优先摄食生物膜表面的种类，而后才摄食生物膜表面下的部分种类,鲍幼体肠道内底栖硅藻的主要种类与附着基上底栖硅藻群落的优势种类基本一致，说明鲍幼体的摄食没有选择性。

（7）正交实验分别检验了N（$NaNO_3$）、P（$NaH_2PO_4{\cdot}H_2O$）、Si（$Na_2SiO_3{\cdot}9H_2O$）、Fe ($FeC_6H_5O_7{\cdot}5H_2O$)四种营养元素对五种底栖硅藻（盾卵形藻微小变种；咖啡双眉藻；柠檬曲壳藻；多枝舟形藻；新月筒柱藻）生长速率及胞外多糖（胶体多糖和附着多糖）含量的影响，找出了五种底栖硅藻各自最佳的营养盐组合。结果显示，氮元素在四种营养元素组合中起主要作用。考虑到鲍鱼幼体的生活习性，选取正交实验结果中，每种底栖硅藻产生附着多糖（胞外多糖的一种）最多的营养盐组合，作为各自的优化培养基配方。后期育苗试验结果表明，优化后培养的底栖硅藻能明显提高鲍鱼幼体的附着率和成活率。

（8） 2006 年 10 月至 2006 年 12 月，分别以五种硅藻（盾卵形微小变种、咖啡双眉藻、多枝舟形藻、新月筒柱藻、柠檬曲壳藻）作附着基上底栖硅藻群落的优势种条件下进行育苗实验,结果表明：五种单一底栖硅藻培养的鲍幼体壳长在实验结束时并没有明显的区别，差异性不显著（$P<0.05$），但在存活率方面，五种单一底栖硅藻培养的鲍幼体经显著性检验，差异性显著($P>0.05$)，尤其是新月筒柱藻更明显，普遍低于其余四组。从藻类密度变化方面来看，育苗前期，各个藻种的密度变化不大；中、后期各个藻种的密度都有不同程度的下降，下降幅度从大到小的排列顺序是：新月筒柱藻＞多枝舟形藻＞咖啡双眉藻＞柠檬曲壳藻＞盾卵形藻微小变种。

（9）2007 年 9 月至 2007 年 12 月，以天然混合种作对照组，分别用优化培养的五

种底栖硅藻对九孔鲍和皱纹盘鲍作实际育苗应用性研究。结果显示：①育苗前期各个实验组鲍鱼幼体的附着密度有所不同；但育苗后期，筛选的五种底栖硅藻的育苗效果都优于对照组（天然混合种）。②育苗期间，各个实验组鲍鱼幼体的平均生长速率略有差异，但差异不显著。

（10）鲍鱼应用实验结果表明，在目前绝大多数鲍鱼育苗场以聚乙烯塑料薄膜作为鲍鱼幼体附着基的情况下，育苗初期培育盾卵形藻微小变种作为附着基上底栖硅藻群落中的优势种，是一个提高鲍鱼幼体成活率的最简单、有效的方法。

关键词：底栖硅藻；鲍鱼幼体；筛选；培育

Screening, Culture and Application of high Quality Food for Abalone Larval

Abstract

This paper concluded studies about the community composition and the law of the changment of benthic diatoms attaching to the substrates in abalone hatcheries of *Haliotis diversicolor supertexta* and *Haliotis discus hannai* in Dongshan and Zhangpu, Fujian Province from September 2005 to December 2007. The relationship between the reasons of the "delinking of the board" of abalone larval and the benthic diatom community was discussed. And the five common benthic diatoms attaching to the substrates during the early breeding period were isolated and cultured. Meanwhile the five benthic diatom were actual applicated in abalone breeding pools, and comparatived analysis of the advantages and disadvantages of the five benthic diatom were done. Finally a simple and effective method were found to improve the survial rate of abalone larval. The results were showed as following:

1.Totally 61 benthic diatom species (including varieties) belonging to 30 genera were identified in benthic diatom community in the substrate of abalone breeding pool. These species were mainly from 5 genera: *Nitzschia*(8 species), *Navicula*(8 species), *Achnanthes*(4 species), *Amphora*(5 species) and *Cocconeis*(5 species). The number of *Cocconeis* species was less other genera species, but the percent of the *Cocconeis* density was more than other genera in most benthic diatom community.

2. The species of benthic diatom community attaching to the substrate of abalone breeding pools were mainly made up of microdiatom and nanodiatom in size, the growth type was mainly attachment in type; the attachment form were mainly shell attachment and the slit shell attachment. And the algaes moving weakly were in majority. It was indicated by comparative analysis of different larval breeding abalone effect on the attachment of the benthic community in the composition of diatoms, that serious from the board of the benthic community diatom species composition of the movement stronger ability of the density of

algae in general was higher than the corresponding percentage of the same batch Breeding has not from the board of algae cell percentage, usually in the range of 14.28% to 23.04%.

3. In August to December, 2006. a full experiment of the four abalone breeding was done, and the results were showed : ① the continous changment of benthic diatom community attaching to the substrate was obvious. The diversity of the middle stage of abalone breeding is higher than both other stages. Although the dominant species had several differences in the different culture time. *Cocc. scutellum var. minutissima* was the dominant species of the benthic diatom community, particularly in the late abalone breeding stage the percentage of the density was generally more than 90 percentage. And *Amphora coffeaeformis*, *Achnanthes citronella*, *Navicula ramosissima*, *Cylindrotheca clostetium* only appeared in the early stage or the mid-stage. ② the abalone larvae growth rates was different in different propagation. but at the end of the experiment, the averages of shell length were all up to 3.38cm, and there were no significant difference ($P>0.05$), ③At the end of the experiment, the difference of abalone larvae survival rate was great different.and there was very significantly ($p<0.05$). and the abalone larvae survival rate was higher with the benthic diatom community more stable.

4. Success or failure of abalone breeding production may have relationship with the community structure and its stability at the same time. The coefficient of variation in the diversity of benthic diatom communities for the success abalone larval breeding was more than that for the failture abalone larvae breeding. And the percentage of the domaint species in the benthic diatom community varyed greatly in the former abalone larvae breeding stage. But in the last abalone larval breeding stage, they had a common domaint species, that was *Cocc. scutellum var. minutissima*.

5. Comparation between different abalone breeding periods of the benthic diatom community attaching to the substrates was done. The conclusion was showed as follow: ① the diversity index of the same batch abalone breeding in the late stage was lower than that in the early stage. And the diversity index of benthic diatom community attaching to substrate in *Haliotis discus hannai* breeding pools was higher than in *Haliotis diversicolor supertexta* breeding pools. ② the richness is generally higher than that in the early stage and in the late stage. And that in *Haliotis discus hannai* breeding pools was still higher than in *Haliotis*

diversicolor supertexta breeding pools. ③ the changment trend of the dominance ratio and the evenness ratio is contrast to the richness ratio, they were higher in the early stage and in the late stage. however the dominance ratio index of benthic diatom community attaching to substrate in *Haliotis diversicolor supertexta* breeding pools was higher than in *Haliotis discus hannai* breeding pools,the evenness ratio was contrast.

6. The analysis results were showed: the gut content of abalone larval showed that the features of different shell length abalone larvae were closely related to the biofilm's vertical structure. That was abalone larvae feeding benthic diatom species which were on the surface of the biofilm. And then feeding the sec-surface species of the biofilm. The main species with the content of the gut of abalone larvae were basically the same as the advantage species of the benthic diatom communities. which was showed that the feeding of abalone larvae has no selectivation.

7. A test of N($NaNO_3$), P($NaH_2PO_4 \cdot H_2O$), Si($Na_2SiO_3 \cdot 9H_2O$), Fe($FeC_6H_5O_7 \cdot 5H_2O$) four elements on the growth rate of the five benthic diatoms and its extracellular polysaccharide content in Orthogonal experiment, and then in turn draw the best combination of nutrients. The results showed N elements played a major role among four elements. Taking the characteristics of life abalone larvae into account , select five benthic diatoms in the attachment polysaccharide (Exopolysaccharide) the best combination of nutrients as the optimization of their respective medium. The study show that the optimization of medium could promote the abalone larvae adhesion.

8. In October to December, 2006. five species of benthic diatom (*Cocc. scutellum var. minutissima, Amphora coffeaeformis, Achnanthes citronella, Navicula ramosissima, Cylindrotheca clostetium***)** were assayed to evaluate their food value for the postlarvae of *Haliotis discus hannai,* the result was that**:** the shell length of abalone larval cultured five single benthic diatoms had no obvious difference ,and the difference was not significant ($P<0.05$) at the end of the experiment. However, in the survival rate area, five single benthic diatoms cultured abalone larval were obvious by significant test, significant differences ($P>0.05$), especially *Cylindrotheca clostetium* was more obvious. Meanwhile, in the density of algae area, in the early breeding stage, the changment of the density of five benthic diatom was little. But in both other stages, the density of five single benthic diatom have varying

degrees of decline, and the order was *Cylindrotheca clostetium* > *Navicula ramosissima* > *Amphora coffeaeformis* > *Achnanthes citronella* > *Cocc. scutellum var. minutissima* .

9. In September to December, 2007, the practical application of research were held with optimization training methods of five benthic diatoms in *Haliotis diversicolor supertexta* breeding pools and in *Haliotis discus hannai* breeding pools. Meanwhile natural mixed benthic diatom group was contrast. the results showed: ① In the late breeding stage of both abalone larval, although the attachment density of abalone larval had difference in all groups. The effects of five benthic diatom are superior to the natural group.② During both the abalone larvalbreeding stage, the average growth rates have differences in all experimental groups. However, the analysis showed that there was not obvious.

10. The results showed that *Cocc. scutellum var. minutissima* ,as a dominant species of benthic diatom community attachmenting to the substrates was a most simple and effective method of increasing survival rate of abalone breeding. Taken the polyethylene plastic film was still as the substrate of abalone larval in majority of abalone breeding factories in account.

Keywords: Benthic Diatom; Abalone larval; Screening; Culture

第一章 前 言

自古以来，鲍鱼即在中国的饮食文化之中占有重要的地位。所谓的山珍海味， 其中之一指的就是鲍鱼。鲍肉味鲜美，具有很高的营养价值，被称为“ 海味之冠”[1]。其贝壳有清肝明目之功效。国内外市场紧俏，价格一直看好，也供不应求。在古代中国药理论述上，相传其壳可治眼疾, 故有石决明之称。 明朝李时珍所编撰的《本草纲目》中对石决明的药理作用均有所论述。

1.1 鲍鱼养殖现状

近十几年由于澳大利亚、日本、美国、智利等主要产鲍国产量急剧下降，致使国际市场价格不断上涨, 市场前景十分广阔。我国人工养鲍业开始于上世纪 70 年代中期，经过三十多年的发展，在辽宁、山东、福建、广东等地区养鲍业已成为沿海地方支柱产业之一。

1.1.1 鲍鱼的分类及其主要养殖种类的形态

鲍鱼是一种以海藻为食的海生贝类动物，它不同于滤食性的蚌或蛤等双贝壳类生物。在动物学分类上，鲍鱼隶属于软体动物门(Phyllum Mollusca)，腹足纲（Class Gastropoda)，前鳃亚纲(Subclass Presabranchia)，原始腹足目(Order Arehaeogastropoda) 鲍科(Family Haliotidae) 鲍属(Genus Haliotis)。鲍鱼的种类较多，目前国内养殖和研究的主要有以下两种:

(1) 皱纹盘鲍(*Haliotis discus hannai*)：具有一个大而坚厚的贝壳，螺层三层，椭圆形，缝合线浅，壳顶钝。壳边缘有一列突起，有一排以 20 个左右凸起和小孔组成的旋转螺肋，其末端有 4～5 个开口，紧靠突起的外侧有一条与突起平行的凹沟。壳外面深褐绿色，生长纹明显，无大的褶壁，贝壳内面银白色，有绿、紫、珍珠等彩色光泽。

(2)九孔鲍(*Haliotis diversicolor*)：螺层三层，基部缝合线深，渐至顶部不明显。壳顶钝，稍低于体螺层的高度，成体多被腐蚀，露出珍珠光泽。又壳顶向下，从第二螺层中部到末端边缘有一列突起，共约 20 余个;靠体螺层边缘的是 7～9 个开口，其余皆闭塞。壳内面银白色，有珍珠光泽。壳表面绿褐色，生长纹细密，